Transient Data Manager® 2 plots identify steam turbine generator problems

Photo courtesy of Kilroot Power Station

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Kilroot Power Station, located in Carrickfergus, Northern Ireland, has two 300 MW turbo-alternators with dual oil or coal-fired boilers and two 30 MW gas turbines. The first 300 MW unit went into service in 1980. The station was acquired in 1992 by two companies involved in power production, Applied Energy Services (USA), and Tractebel SA (Belgium). The new company created is called NIGEN.

A new Bently Nevada Transient Data Manager® 2 (TDM2) System was installed on Unit 1 in 1993 and on Unit 2 in 1994. The units run at 3000 rpm. See Figure 1 for the machine layout.

Upon startup, following a minor overhaul, TDM2 data plots immediately highlighted a vibration problem at the Exciter Outboard No.10 bearing, where a maximum vibration amplitude of over 380 μm (15 mils) pp was measured by the installed proximity transducers. The shape of the unfiltered Orbit shown in Figure 2 indicated that the high vibration was caused by a heavy downward load, such as can be caused by severe misalignment. This was corroborated by the fact that the Exciter No.10 bearing was already known to be misaligned high.

The TDM2 System immediately proved beneficial. As there wasn't time to realign the machine to reduce the load on the bearing, Laborelec and NIGEN's engineers used the TDM2 data to balance the exciter in situ to decrease the vibration levels as much as possible by eliminating the effects of unbalance. This was the most cost-effective option, due to the strict time constraints and cannot be regarded as a routine balancing job. The decision was based on the diagnosis of an intermittent rotor rub near the No. 9 bearing.

Since severe misalignment can cause shaft cracking, the TDM2 vibration trend plots were continuously monitored for indications of cracks. Symptoms which can indicate shaft cracks are unexplained changes in 1X running speed vectors, 1X slow-roll vectors and sometimes 2X running speed vectors.

Vibration changes

In February 1994, changes were noted in the No.10 bearing vibration behavior, following a 34-hour shutdown. Figure 3 shows that the highest measured vibration amplitude had decreased to 230 μm (9 mils). The orbit shape had become more normal, indicating a significant reduction in the load on the bearing. It was immediately suspected that bearing wear may have occurred. Figure 4 is a shaft centerline position trend plot covering the period of the shutdown. It shows that, following the restart, the shaft centerline position during normal running was 230 μm (9 mils) lower than the running position before the shutdown. The plot also shows that the shaft centerline moved progressively lower in the bearing during the time that the machine was shut down, as the shaft was turned slowly by the turning gear. Thus, the indication was that the bearing may have wiped when it was running on the turning gear, which improved the shaft alignment and consequently reduced the load on the bearing.

Figure 5 is a shaft centerline plot which was constructed from TDM2 trend data. It shows the running shaft

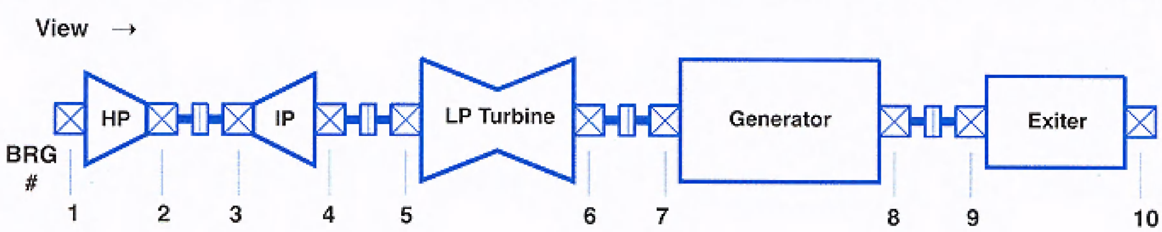

Figure 1
Machinery configuration diagram

centerline position changes that occurred between load running following the overhaul in July 1993 until immediately prior to the shutdown for the next overhaul in May 1996. The movement that occurred during the shutdown (January 29 and February 3, 1994) is clearly shown on the plot.

Shaft centerline movements continued to occur. By November 9, 1994, Figure 5 shows that 515 μm (20 mils) of movement had taken place, with the vibration amplitude decreasing and the Orbit becoming less flattened (Figure 6) after the exciter holding down bolts had been tightened. The latest reading, on May 2, 1996, prior to the shutdown, indicated that a total shaft movement of 850 μm (33.5 mils) had taken place. Figure 7 shows that vibration levels had increased slightly to 220 μm (8.5 mils).

The original bearing white metal thickness was 2500μm (~98 mils). When the bearing was checked during the 1996 overhaul, 1980 μm (78 mils) of bearing wear had occurred. Therefore, it was likely that significant wear had occurred during the balance exercise, before the initial running gap voltages were taken in 1993.

Turbine vibration variations

Another machine problem was also discovered by looking at TDM2 data. When the generator load was reduced or increased, subsequent vibration excursions were noticed at the No. 1 through 4 bearings. Figure 8 shows a typical vibration plot versus time. The three curves on the plot show the maximum, mean and minimum direct vibration values measured during the sample period. The variation was caused by changes in the 1X vibration vector, as can be seen from the 1X vector trend polar plot in Figure 9. The plot shows that the 1X amplitude initially increased, accompanied by an increase in phase angle, before decreasing and returning to its original value. This is one of the typical responses that can be produced by a radial rotor-to-stator rub. An explanation of the mechanism which produced the changes was published in an article, "Thermal Rub Effect in Rotating Machines" by Dr. Agnes Muszynska in the March 1993

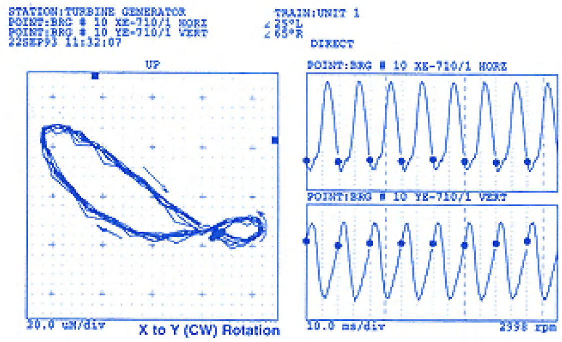

Figure 2
Unfiltered orbit/timebase plot, showing high vibration caused by a heavy downward load.

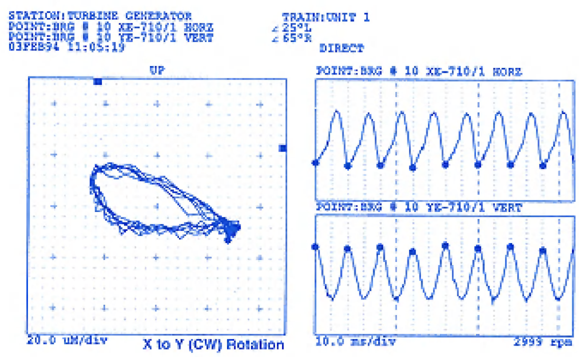

Figure 3
Unfiltered orbit/timebase plot after the restart, showing a more normal orbit shape, due to a reduction in load at the bearing.

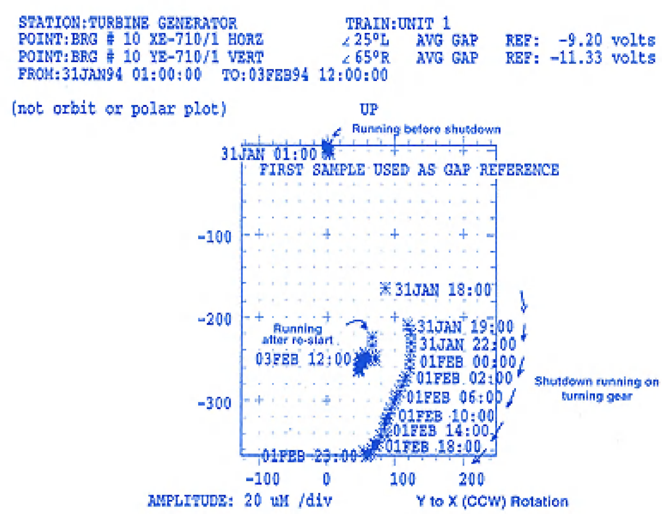

Figure 4
Average shaft centerline position plot covering the shutdown period, showing a lower running position after the restart.

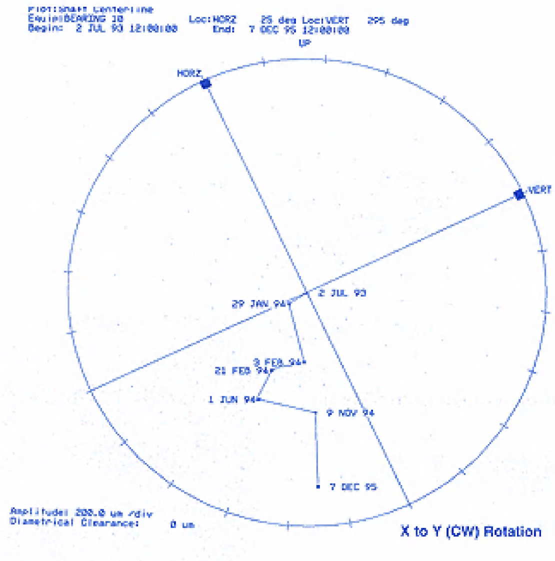

Figure 5
Shaft centerline trend plot, showing the on-going bearing wear.

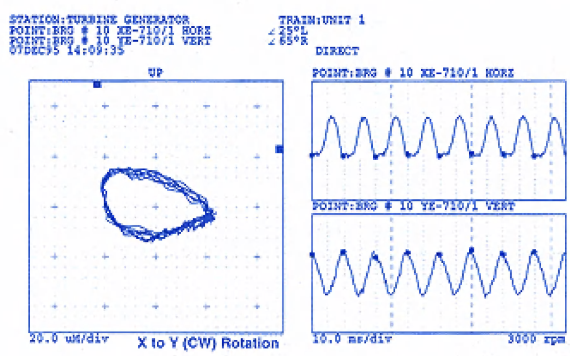

Figure 6
Orbit/timebase plot after tightening the exciter holding down bolts.

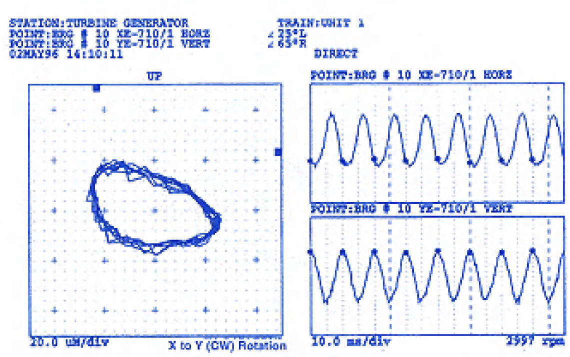

Figure 7
Orbit/timebase plot prior to the 1996 shutdown.

Orbit. On this occasion, the rub cleared after one cycle of the excursion, but on other occasions the rub only cleared after several cycles. Site personnel also noted that, over a period of several months, the severity of the vibration variations progressively decreased, indicating that repetition of the rub was producing wear which would ultimately increase the radial clearance until the rub did not recur.

The load reduction was accompanied by a decrease in the reheat steam temperature to the IP (Intermediate Pressure) turbine. As the vibration excursion didn't directly coincide with the load change, but followed it, the most likely cause was the resulting temperature change, not the load change itself. Therefore, it was considered likely that elevation changes at the bearing pedestals would occur in response to the decrease in steam temperature, altering the rotor-to-stator radial clearance.

Optical measurement

Consequently, thermal elevation measurements were carried out on the first two pedestals (containing the No. 1 and No. 2 and 3 bearings, respectively) using optical methods, to determine how much the pedestal moved vertically as the steam temperature changed. This was accomplished by using a precision Jig Transit Telescope and an optical tooling scale, mounted, in turn, on the half-joint at each corner of the two pedestals. Height readings were taken at full load with the steam temperature at 540° C (1002° F) and at reduced loads as the steam temperature was progressively decreased to 500° C (931° F).

The No. 1 bearing pedestal behaved in a normal manner, with a general decrease in height as the steam temperature decreased. Figure 10 shows the relative elevations of the No. 2 and 3 bearing pedestal. The solid block on Figure 10 indicates a true horizontal plane, for reference purposes. The dashed lines show the actual pedestal half-joint elevation at full load with a 540° C (1002° F) steam temperature. The solid lines give the corresponding half-joint elevation with a steam temperature of 500° C (931° F). After the steam temperature

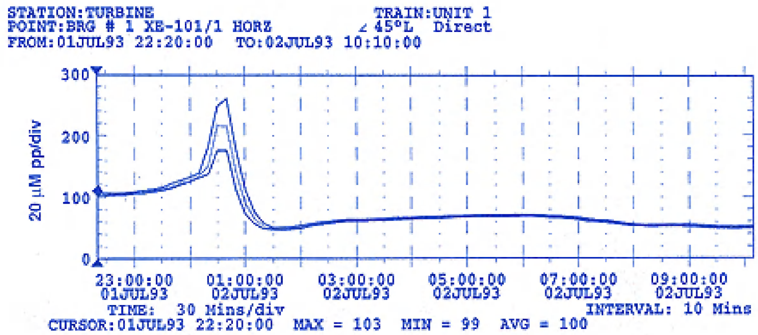

Figure 8
Trend plot, showing typical vibration changes over time, due to the rub.

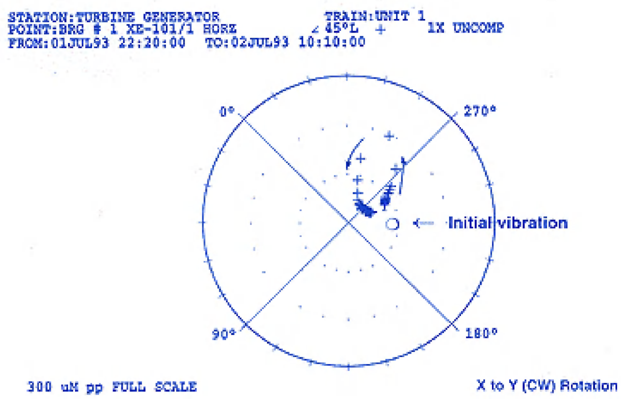

Figure 9
Acceptance Region plot, showing initial vibration (marked with an o) and vector change.

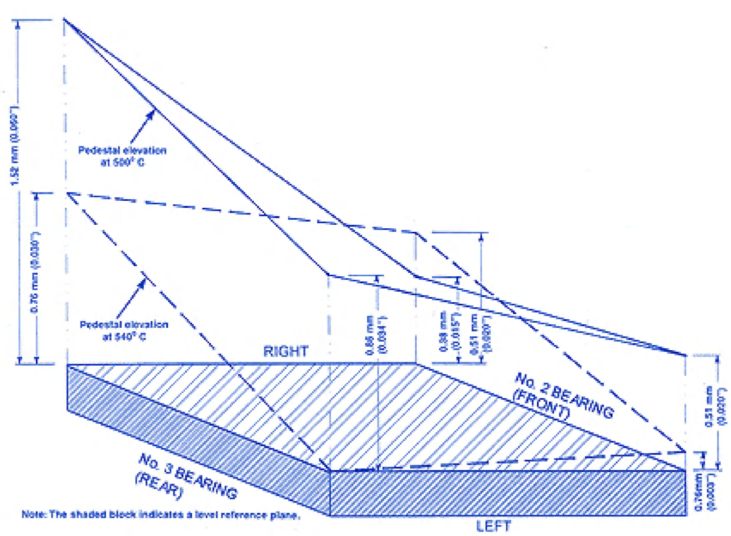

Figure 10
Pedestal thermal position study, showing relative elevations.

was reduced, the front right-hand corner of the pedestal moved down 130 μm (5 mils), as expected. However, at the other measurement positions, the pedestal rose by between 430 and 760 μm (17 to 30 mils), indicating the pedestal twisted as the steam temperature decreased.

Conclusions

If the pedestal movement had been a direct result of the steam temperature changes, the twist wouldn't have been expected to occur, and a general reduction in pedestal height would have been expected as the temperature decreased. Therefore, it was concluded that the twisting of the pedestal was possibly caused by pipe strain on the IP turbine casing, which was, in turn, transferred to the No.2 and 3 bearing pedestals.

A subsequent survey of the steam pipe supports did not indicate any anomalies, making it likely that the rub was caused by casing distortion. When the machine was opened up for the overhaul in May 1996, severe wear caused by a rub was found on the pedestal oil wiper adjacent to the No. 3 bearing. Rubs were also seen at the IP front steam glands and at the stage 3 and 4 diaphragms. Information obtained from the orientation of the rubs was used to modify the rotor/casing alignment during the rebuild.

In both cases, the TDM2 System allowed the problems to be identified and the on-going trend plots provided information to show that it was safe to continue running the machine until the 1996 overhaul.

Contact your nearest Bently Nevada sales and service office for further details about the optical method of position measurement, which is quick to set up. In addition, checks can be repeated at a later time, without leaving the equipment attached to the machine.■

Editor's Note: Copies of the article, "Thermal Rub Effect in Rotating Machines" by Dr. Agnes Muszynska are available upon request. Please fax the Orbit Editor at (702) 782-9337 or call (702) 782-3611 ext. 9493.